# Complementing Remote Sensing Systems In Flood Mitigation and Preparation

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## Background

As a result of their response to the many natural disasters of the 1990s, the Federal Emergency Management Agency ( FEMA) has been directed by the U. S. Congress to place mitigation of impacts from future natural hazards as its highest priority in working with state and local governments. The National Flood Insurance Program (NFIP), and its related flood-risk studies and flood hazard mapping activities, are increasingly important mitigation support functions. A current focus is on map modernization to speed up the flood mapping process, lowering its cost, and increasing the accuracy of these results. A further emphasis is on more support to the local areas as exemplified by "Project Impact." This project's purpose is to mitigate disasters' impacts by taking actions in advance of these events. These initiatives by FEMA, when coupled with the National Mitigation Strategy Goal, and one of its objectives of applied research and technology transfer, has precipitated a greater need to use existing and emerging remote sensing assets to the fullest. Since the information element of "elevation" is so critically important in many flood mitigation planning and preparation scenarios, the collection, processing, and use of this set of multi-use information is of highest priority. A parallel objective is to

evolve a suite of remote sensing system options that can be used during a single flight pass to collect many types of data to be combined to support multi-hazard mitigation and rapid response needs.

## The California Condition

In early 1997, the El Nino related flooding threats were causing serious concern in the San Joaquin and Sacramento Valley, CA areas. FEMA was requested to orient some of its flood mitigation efforts towards producing more accurate elevation data to be used for water flow prediction analysis. Additionally, because of the Corps of Engineers downgrading of the levee reliability in the area around Lakewood, CA, improved elevation information was needed to guide the evaluations of structures for flood insurance. In response, FEMA decided to employ Interferometric Synthetic Aperture Radar (IFSAR) and LIght Detection And Ranging (LIDAR) collection systems to provide for these existing requirements. At the same time FEMA would evaluate the possibility of these technologies being fused to satisfy the long-term map modernization effort by creating a technology that could be transferred to lower the cost of mapping elevations.

## Remote Sensing Options

Over the past decade there has been a significant maturing of many remote sensing collection systems and related data processing sub-systems. Many are candidates for full operational use. To evaluate these technologies, FEMA has established a Remote Sensing and Emerging Technologies Evaluation Project in support of technology transfer for multi-hazard mitigation, preparation, response and recovery—with the emphasis on mitigation for map modernization at this time. The current,

preliminary results from using IFSAR and LIDAR in California are part of this project.

IFSAR

This particular type of remote sensing "tool" has emerged as a very useful option for producing elevation information over large geographic areas (entire valleys, counties, etc.). The digital elevation model (DEM) produced from this type of system normally has an absolute vertical accuracy in the 1-2 meter range. One of the advantages of IFSAR is that many thousands of square miles can be collected in one day by a high-flying aircraft. One of the disadvantages is that the ground processing is fairly intense and takes significant computing resources to result in a quality-checked DEM within a few weeks.

California Collection. In the early fall of 1997, a collection mission of IFSAR was accomplished over the central valley areas of California. FEMA transferred funds to the U.S. Army Topographic Engineering Center (TEC), Corps of Engineers who had a contract with the Environmental Research Institute of Michigan (ERIM), who developed IFSAR-Elevation (IFSAR-E) configuration for the mission. ERIM sub-contracted with Intermap to collect the IFSAR-E and produce DEM values at approximately 1.5 meters absolute vertical accuracy. The IFSAR-E and DEM information has been provided to the California State Government, TEC, and FEMA. It is currently under evaluation.

LIDAR

This remote sensing technology has been evolving for a number of years. The resultant DEM requires coordinated processing of the laser-lighted ground-spot

returns, the Global Positioning System (GPS) signals along the flight path, and the inertial navigation unit (INU) values at frequent, regular intervals to record the pitch, yaw, and roll components of the aircraft's motion (similar to the coordinated processing performed with IFSAR sensor systems). Processing techniques have been developed to the point that DEM results can be available within a few days, even a few hours, if needed, after the time of collection. The relative vertical elevation accuracy of the DEM points are in the range of sub-foot values with absolute vertical accuracies between 1 and 2 feet. Currently, it is most beneficial to use LIDAR for small areas (a few kilometers square), or along extensive, narrow ground tracks where high detail elevation/height information is needed. As a result, LIDAR has historically been employed for obtaining elevation information along ocean coasts, waterways, lake shorelines, levees, transmission lines, road networks, etc.

Central Valley Area California Collection. In the fall of 1997, FEMA coordinated with the NASA Wallops Island Flight Test organization performing LIDAR collection along the Oregon and California coastlines. A 10-hour mission was flown by the NASA LIDAR in their fixed-wing aircraft over an extensive section of the levee network within the same central valley areas previously covered by the IFSAR-E a month earlier. These data were processed by NASA and are now in the evaluation stage at TEC. This evaluation will include combining the LIDAR and the IFSAR-E derived DEMs to further refine and attempt to improve the vertical accuracy of many of the IFSAR-E points, as well as providing accurate elevations for many of the levee tops. A technique of "differencing" will be employed using the

LIDAR values similar to how ground control is used in photogrammetric mapping to improve the vertical accuracy of the IFSAR-E derived DEM values near the levees, as well as to provide very accurate elevations for the levee tops. LIDAR and IFSAR-E data sets will be fused as follows: Step 1-Both DEM data sets will be imported into ARC/INFO as Triangulated Integrated Network (TIN) geographic data sets associated with reference control points. Step 2-The IFSAR-E DEM points in the LIDAR regions will be extracted, and the differences calculated between them and the remaining IFSAR-E DEM points outside of the LIDAR regions. Step 3-LIDAR DEM corrections will be applied to IFSAR-E DEM data by calculating the difference between the elevation of the IFSAR-E points and the LIDAR points within the LIDAR boundary areas, and applying the difference to all the IFSAR-E points outside the LIDAR boundary areas. Step 4-Actual data fusion will be performed by generating a TIN file for the mean value of the DEM points and a separate TIN file for the median values. Step 5-The RMS and standard errors of the mean and median values in the overlap areas will then be used to establish the expected accuracy of the DEM data fusing procedure. Step 6-Products will be bare earth DEMs, DEMs including structures, an overlay of the Letter of Map Revisions (LOMRs) with the structures, and a statistical analysis of the differences between the structures' annotated elevation and the LOMR elevation. Results of this evaluation should be available in mid-summer 1998.

Los Angeles Area California Collection. A set of LIDAR collections will soon be completed over the currently flood-mapped AR Zone near Lakewood, CA. The thrust of this series of tasks is to obtain LIDAR collections from a number of

LIDAR system configurations (3-4), process the data for DEM and other structure related locations, and heights relative to the topography, and evaluate the results for production operations in the future. This set of LIDAR evaluations will allow: 1) a comparison of cost and accuracy for various LIDAR systems, and 2) how the use of LIDAR can support the determination of the lowest adjacent grades for structures potentially in flood risk areas. Results from this evaluation should be available in the late summer of 1998.

## Summary Considerations

Since time responsiveness, cost reductions, and useability are all key considerations for map modernization planning at FEMA, these considerations provide the basic guidelines for the evaluations of the candidate remote sensing systems. Acquisition factors, processing steps and the product formats all play important roles in whether a particular remote sensor system or combination of systems should be used or not. Since DEM information is the objective of IFSAR and LIDAR collections, and that particular data element has such pervasive benefits in multi-hazard mitigation--especially flood mapping; these systems warrant concentrated evaluation efforts to establish how to operationally use them at this time. One of the future objectives to which these systems are likely to contribute is the configuration of a single pass, multiple-use collection capability, which can assist with mitigation and rapid damage assessment requirements. Terrain elevation, structures characteristics, soil permeability, ground cover categorization, and infrastructure conditions may all be derived from one over-flight with the proper combination of multi-sensors as they become more miniaturized and less expensive.